MD FOOD

Sweet Solace

▪ It was the basic ingredient of ambrosia and nectar, the favorite food and drink of the Greek gods; Pliny the Elder declared that it prolonged life, a Chinese emperor called it the "drug of immortality," and "flowing with milk and honey" was the Biblical description of the Promised Land. ▪ Since antiquity, the sweet viscid fluid produced by honeybees from flowers was treasured as a medicinal, mystical, and miraculous substance that acted as an elixir of youth, an aphrodisiac, an antiseptic, and the world's oldest sweetening agent. ▪ Today, honey is regarded as a nutritious, easily absorbed, quick-energy food. Honey's hygroscopic properties make it an essential product in many industries, and it serves as a component of some pharmaceutical products. ▪ LORE. The first reference to honey survives in medical prescriptions on a Sumerian tablet that dates from about 2100 B.C. Later, honey continued to serve as medicine to the Babylonians. After the Hittites conquered Babylon, they regulated the price of honey and imposed fines for the theft of hives and swarms. ▪ The bee was the sign of the king of lower Egypt; after King Menes founded the First Dynasty (ca. 3400 B.C.), he was known as "the beekeeper." The importance of bees and honey survives in numerous Egyptian hieroglyphic carvings in temples, on sarcophagi, obelisks, statues, and other monuments, including the famous Rosetta Stone and the colossal tomb of Ramses III. On occasion honey was used as an embalming fluid; honey, honeycombs, and honey cakes also served as food for the dead. The honey discovered in Tutankhamen's tomb was still palatable after 3000 years. ▪ Much of the honey in Egypt was used by priests in ceremonials. To collect it, the Egyptians devised an ingenious migratory system of beekeeping. At the end of October, tiered mud hives were moved up the Nile on rafts

and floated downstream to exploit the succession of plants flowering after the annual floods.

Honey also played a vital role in many mythologies. Greek literature, including the *Iliad* and the *Odyssey*, is rich in praise of its nutritional, medicinal, and life-giving properties, especially wild thyme honey from Hymettus, the fabled mountain in ancient Attica, still famous for its rich product. In Greek and Roman mythology, ambrosia (milk and honey) was the food of the gods; nectar, compounded of fermented honey and spices, was the celestial drink that imparted youth, beauty, vigor, and immortality to the gods on Mount Olympus. Zeus was called Essenos (bee king) by Homer because he was nursed on milk and honey. Many ancient Greek coins depict Zeus on one side and a bee on the other.

Honey also symbolized love: Dionysus, the god of fertility, was worshiped as a honey god; Eros, the god of love, was often represented as a honey thief; Kama, the Hindu god of love, was depicted with bees to symbolize the sweetness and sting of love.

Aristotle suggested that honey was "dew distilled from the stars and rainbow"; Plutarch romanticized honey as the saliva of the stars. Some believed that the nectar flowed from the moon, and in Hindu mythology, *madhukara*, the epithet for the moon, means honey giver; Artemis, the moon-goddess, is often portrayed in the shape of a bee. In rituals, sacrificial offerings of honey cake were common, and a beehive was among the things offered in the annual rites to the Germanic god Neckar.

Some of the earliest observations of beehive activity were recorded by Aristotle in his *Natural History*. The most prolific writer on the subject was Vergil, whose fourth *Georgics* was devoted largely to the subject of beekeeping. He called honey "the heavenly ethereal gift" and correctly concluded that bees were attracted by the scent of flowers. Pliny the Elder, in the eleventh book of his *Historia naturalis,* was impressed with the longevity of beekeepers. In a region between the Apennine Mountains and the Po River, thickly populated with beekeepers, he found 124 persons on the tax rolls of 76 A.D. who had passed the century mark.

Early Druid bards celebrated Britain as the Isle of Honey. One of the early uses of honey was the preparation of alcoholic drinks. Anglo-Saxon chieftains were blamed for "bringing about the ruin of Britain" because they went into battle drunk on mead, fermented drink of honey, malt, and yeast.

Honey was also an important commodity: Charlemagne's *Capitulares Karlomanni* included regulations for the honey industry. Taxes and tributes were often imposed in payments of honey and beeswax.

Considered a sacred substance honey played a role in birth, marriage, and funeral rites. Many famous women valued its cosmetic properties, including Cleopatra; Agnes Sorel, mistress of Charles VII; Mme. du Barry, mistress of Louis XV. Nero's wife Poppea used a mixture of honey and asses' milk to soften her skin; England's Queen Anne applied a hair conditioner concocted from honey and olive oil.

Honey was also used to treat the ailments of animals. In Poland it was rubbed into the eyes of cows to prevent the pestilence; honey was recommended as a food and medication for falcons. Other uses of honey in the 13th century were contained in *Dels Auzels cassadors* (*Birds of the Chase*) written by Daudé de Pradas, a Provençal ecclesiastic.

SOURCE. Man has always been fascinated by the industry and social organization of the honeybee. A typical colony includes a queen bee capable of laying up to 250,000 eggs a year, as many as 60,000 workers (sexually undeveloped females), and several thousand drones (male bees) develop from unfertilized eggs. The function of the drone is solely reproduction. The drone that impregnates the queen on her mating flight dies; the rest are excluded from the colony at harvest time to succumb to starvation or the weather.

The colony is maintained through a harmonious division of labor among the workers who protect and nurture the queen and her young; clean and guard the hive, and gather as much as 1000 lb. of nectar, pollen, and water in a year's time. An adult worker in an active season lives about six weeks, spending three weeks in the hive as a house bee and three weeks as a field bee.

The honeycomb, molded from tiny flakes of beeswax secreted on the underside of the insect's abdomen, is a model of artistry, symmetry, and functionality. The thin-walled, double layer of a uniform, hexagonal, prismatic form is built with an economical use of space and material. The back-to-back, six-sided cells allow one floor to serve as the base for two cells. The free surfaces are vertical; the long axes of the cells, horizontal. Capillary action holds the honey in the cells until they are sealed; honey is stored as food for the larvae and the colony during the winter months.

The size and use of the cells vary, depending on the needs of the colony. In general, honey is stored toward the top of the combs and pollen in cells around the broodnest below the honey. During a honey flow the comb is usually white, but shade depends on the color of the nectar and pollen from which it derives. If sainfoin is the predominant blossom, the comb is deep yellow; one from heather is snowy white.

During honey flows, a colony can collect as much as 15 lb. of nectar in a single day. About 160,000 bees are involved in the production of 1 lb. of honey. Some 80,000 field bees log 50,000 to 300,000 mi. to collect about 4 lb. of nectar from a minimal two million flowers; another 80,000 house bees evaporate the moisture from the ripening honey. In most locales, the honey flow begins in June but the length varies by region and the yield depends on a number of factors, including weather and the number of wild honey producing plants in the area.

HONEY. Nectar, which contains from 50 to 80 percent water, becomes honey through a two-stage process that converts its principal sugar, sucrose, into the fruit sugars, fructose and dextrose at levels of about 40 and 34 percent respectively through enzymatic action. Evaporation follows to reduce the space required for storage and prevent premature fermentation by deterring the growth of yeast.

Catalytic changes begin with the enzyme invertase in the field bee's honey stomach and continue in the hive where the nectar is distributed to the house bees who add enzymes and reduce the mois-

Early woven Central European beehive, opposite, is covered with clay and decorated as a demon with its tongue out as an entrance and exit for the bees. Ozark bee hunter samples a comb of wild honey, above, an important sweetener for hill folk. At an agriculture school in Israel, below, students study bees at the school apiary.

ture through repeated regurgitations. The predigested nectar is stored in cells; other bees, called ventilators, stationed within the hive and especially at the entrance, fan their wings to hasten evaporation. Once the moisture is removed, new nectar is distributed on top. Cells are capped with airtight wax when they are filled with ripened honey.

The flavor and color of honey depends largely on the plant from which the nectar is gathered, ranging from the pale and delicate clover honey to the dark and pungent buckwheat honey, once common but now scarce. Each plant also imparts an aromatic constituent that affects the flavor. Prized honey is produced from more than one floral source, mixed naturally in the hive.

Characteristics of a specific type of honey can vary, depending on the topography, soil type, and weather. Each season's crop changes somewhat; honey from the same flower can also differ. Alfalfa honey is light-colored in New England but amber in California and Arizona. Alfalfa honey is one of the most popular honeys in the United States, along with honey from other legumes usually marketed under the name "clover honey" or "clover blend."

Other sources of American honey include the apple blossom, basswood, blueberry, dandelion, eucalyptus, goldenrod, orange, palmetto, privet, sage, and wild strawberry. A prized variety is tupelo honey from western Florida, mostly along the swampy Apalachicola River region. Costly operations are involved in obtaining tupelo honey, including the transport of bee colonies on specially built barges, the use of high wooden platforms to guard the colonies against floods, and mechanized methods for the removal of the honey stored in the combs. In summer, the bees are removed because the area lacks any other major honey plants to sustain them. In addition to its fine flavor, tupelo honey is slow to granulate, which is why most of it is sold to pharmaceutical firms.

Honey from several sources may be blended for uniform texture and color. But about 200 kinds of honey, both imported and domestic, are marketed under the names of their floral types. Imported honey includes thick Bavarian pine-blossom honey, lotus honey from India, dogwood honey from Jamaica, leatherwood honey from Tasmania, snow-white honey from Siberia, and black-locust honey from Italy. France's sea-green honey from the blossoms of gooseberry bushes and sycamore trees is considered a great delicacy and the crystal white, granular rosemary honey from Narbonne was mentioned by Julius Caesar. Among the world's finest are acacia honey from Hungary and wild thyme from Mt. Hymettus in Greece.

CHEMISTRY. In general, the darker honeys contain more acid, nitrogen, ash, and complex sugars, while the lighter and more popular ones have a higher percentage of fructose and dextrose. Analyses of some 92 samples of different honeys showed averages of 40.5 percent fructose, 34 percent dextrose, 1.9 percent sucrose, 17.7 percent water, 1.5 percent dextrins and gums, and 0.18 percent ash. It also has small amounts of various vitamins, notably C and members of the B complex, and enzymes, such as diastase, inulase, catalase, and invertase.

Other substances found are plant-coloring materials; suspended solids, such as pollen grains and tiny particles of beeswax; copper, calcium, and iron, and small traces of silica, manganese, chlorine, potassium, sodium, phosphorus, sulfur, aluminum, and magnesium.

MARKETING. Honey is marketed in several forms: the most popular are liquid honey, finely granulated honey of creamy consistency, and comb honey, which connoisseurs prefer for its delicate aroma. Extracted honey is immediately heated to not more than 160 F. to dissolve crystals and retard crystal formation, then quickly cooled, strained, and packed in sealed containers. Extracted honey is also sold unfiltered and uncooked.

Creamed honey is processed to encourage granulation. Both liquid and granulated honey are some-

Said to be the world's largest bee market is the annual outdoor market at Veenendaal, Holland, where some 2000 hives are traded.

times blended, homogenized, and held at a cool temperature to speed granulation. Comb honey granulates more readily than extracted honey but almost all honey will granulate. Contrary to popular belief, crystallization is not a sign of impurity nor spoilage.

Adulteration of honey in the United States is punishable by a heavy fine. Such simple adulteration as the addition of sugar water or sucrose solution is easily detected. The fructose, which has a higher concentration in honey than dextrose or sucrose, turns polarized light to the left in pure honey.

Worldwide production of honey is about 900 million lb. but in the last few years a general shortage has developed. In the United States, production from an estimated 4.3 million bee colonies was 176 million lb. last year, a drop of 11 percent from 1976. The value of the crop was $93.4 million; 6 percent below the previous year. The yield from individual colonies has also declined.

The yield is adversely affected by plant diseases, insect pests, and the acreages of nectar-producing plants. But in three major honey producing states, the drop was blamed on weather: the cool temperatures in New York and Florida and the extended drought in California. The United States, Mexico, Argentina, Australia are the largest exporters; West Germany is the greatest importer of honey.

Estimates place the number of beekeepers in the United States at somewhere between 200,000 and 300,000, including backyard beekeepers with one colony. The development of commercial apiaries has been helped by specialized and mechanized processing techniques and the development of large-scale migratory beekeeping. Important contributions were made by the Reverend Lorenzo Lorraine Langstroth (1810-1895), an American, known as the father of modern beekeeping for his design of the moveable frame hive, and Charles Dadant of Illinois who improved on Langstroth's principles. Knowledge of beekeeping has spread by journals, associations, and honey shows. In addition, honey production has led to the development of industries that sell bees or that supply hives, tools, and equipment.

USES. Honey is a nutritious, flavorful food that is easily absorbed and is known for its anti-hemorrhagic value, its ability to inhibit harmful bacterial growth, and its hygroscopic quality. This characteristic of absorbing and retaining moisture from the air makes it a valuable product for bakers in the United States who use about 25,000 tons each year, and to the tobacco industry here and abroad, which accounts for at least 2000 tons annually.

Some 70 to 100 tons of honey are used each year for preparing processed meats and another 25 tons in the manufacture of cosmetics, including lotions,

Most of the honey produced in the United States is used in preference to sugar to sweeten food. As shown here it is an ingredient in a spiced honey cake.

handcreams, facial masks, hair conditioners, and shampoos. Honey is also sprayed on coffee beans to improve their flavor and it is a component of Benedictine, the celebrated liqueur originated by Benedictine monks. But the bulk of the honey produced in the United States is consumed by homemakers as a food, a sweetener, and in baked goods.

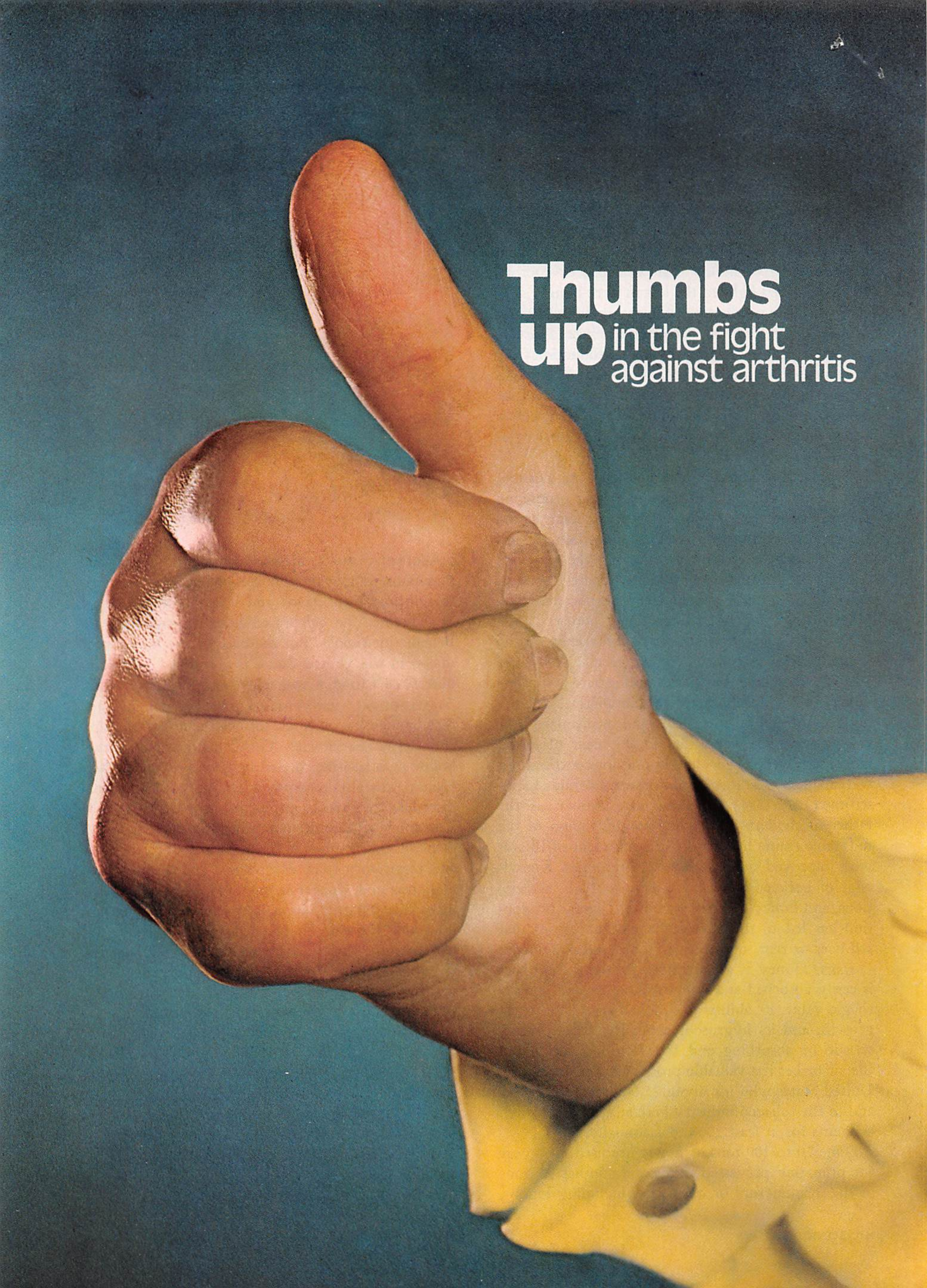
MEDICINAL PROPERTIES. Hippocrates claimed that honey cleaned sores, softened ulcers of the lips, and healed carbuncles. Celsus recommended raw honey as a laxative; boiled honey to cure diarrhea. Honey was also recommended for gastrointestinal disorders, respiratory problems, as a throat gargle.

In modern times, honey remains a popular ingredient of folk medicine, taken mainly for laryngitis and respiratory-tract complaints, and a daily dose of honey and vinegar is regarded as a panacea for many ills. Pharmaceutically, at least 200 tons are used worldwide in cough medicines.

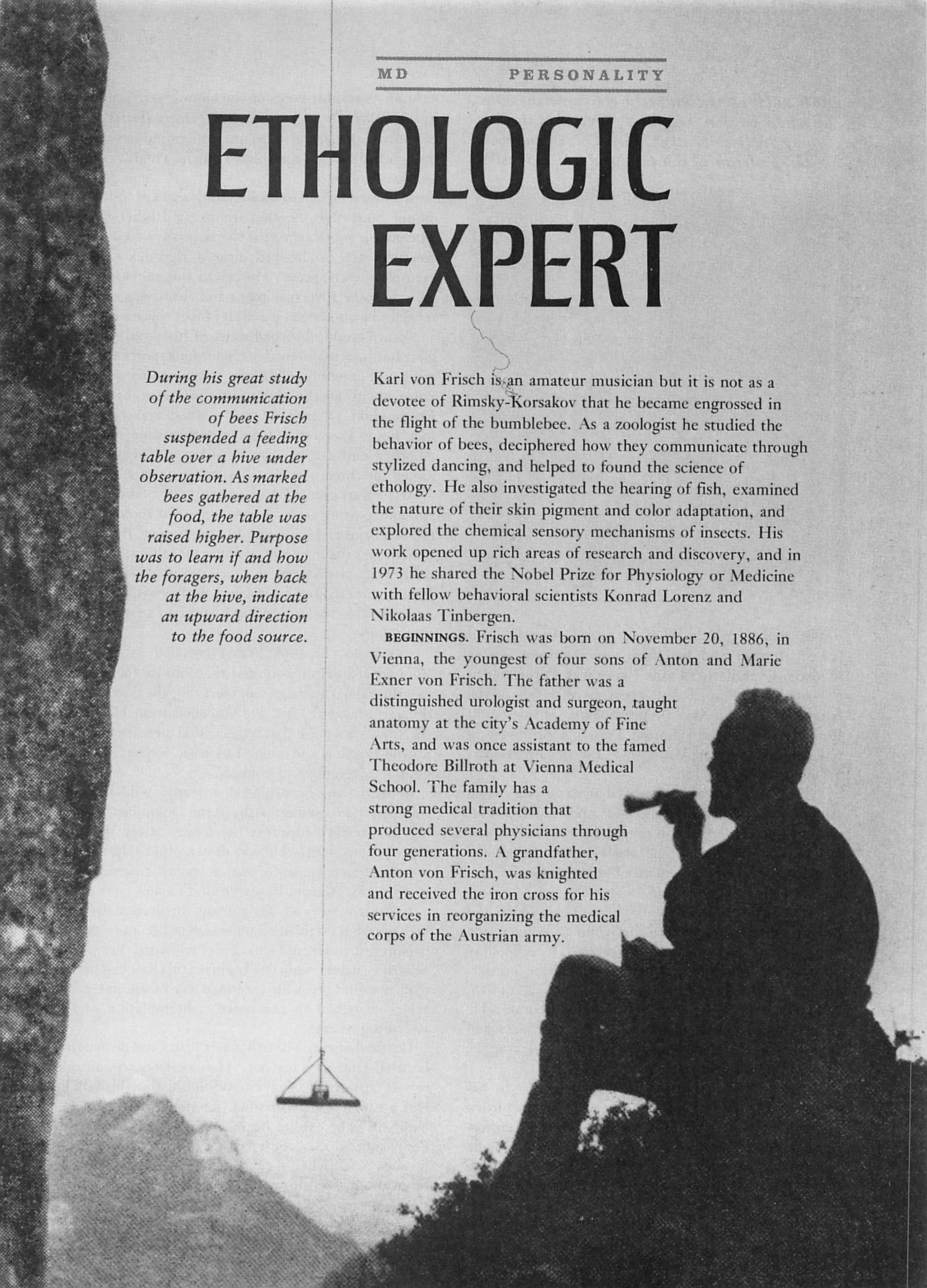
A number of clinicians have reported on the treatment of wounds and burns with honey. The viscosity of honey makes it a good barrier, its water solubility allows easy removal, and its mild non-corrosive properties prevent additional harm to tissues, whether healthy or damaged.

Honey has also been shown to have antibacterial effects. Its relatively high fructose content makes it useful to speed the metabolism of alcohol, a popular antidote for "hangovers." It is recommended as an easily digested, palatable carbohydrate for children, invalids, the elderly.

SUMMING UP. Food for the gods.


Thumbs up in the fight against arthritis

ETHOLOGIC EXPERT



During his great study of the communication of bees Frisch suspended a feeding table over a hive under observation. As marked bees gathered at the food, the table was raised higher. Purpose was to learn if and how the foragers, when back at the hive, indicate an upward direction to the food source.

Karl von Frisch is an amateur musician but it is not as a devotee of Rimsky-Korsakov that he became engrossed in the flight of the bumblebee. As a zoologist he studied the behavior of bees, deciphered how they communicate through stylized dancing, and helped to found the science of ethology. He also investigated the hearing of fish, examined the nature of their skin pigment and color adaptation, and explored the chemical sensory mechanisms of insects. His work opened up rich areas of research and discovery, and in 1973 he shared the Nobel Prize for Physiology or Medicine with fellow behavioral scientists Konrad Lorenz and Nikolaas Tinbergen.

BEGINNINGS. Frisch was born on November 20, 1886, in Vienna, the youngest of four sons of Anton and Marie Exner von Frisch. The father was a distinguished urologist and surgeon, taught anatomy at the city's Academy of Fine Arts, and was once assistant to the famed Theodore Billroth at Vienna Medical School. The family has a strong medical tradition that produced several physicians through four generations. A grandfather, Anton von Frisch, was knighted and received the iron cross for his services in reorganizing the medical corps of the Austrian army.

Frisch and his three brothers were musicians. Otto, far left, a surgeon, and Ernst, director of the Salzburg Studienbibliothek, played violin and viola; Hans, professor of constitutional law, was cellist.

Maternal ancestors were of mixed Austrian and Jewish descent and had won equal prominence as scholars. Grandfather Franz Exner was a professor of philosophy in Prague and others on that side of the family were professors of physiology, physics, and Roman law. Uncle Sigmund Exner, a professor of physiology at Vienna University, exerted a particular influence on young Karl.

The boy was tutored at home in his early years, then attended a convent school and later a prestigious Gymnasium (secondary school) taught by the Benedictine order. He was an indifferent scholar in such subjects as Greek, Latin, and mathematics but took an avid interest in biology.

Karl was fascinated by animal life of every kind and his indulgent parents permitted him to convert the home into an ever-growing menagerie. His schoolboy diary reveals that at one point he was tending 9 different species of mammals, 16 species of birds, 27 of fish, 26 of terrestrial vertebrates, and 45 nonvertebrates. He taught his pet birds to perch on his shoulders and perform tricks and he spent endless hours observing the habits of all his creatures.

Once, he noticed that the sea anemones in his aquarium began to wave their tentacles when he turned on the light. Since they were eyeless, the boy's curiosity was aroused and he devised a series of experiments to learn whether they were reacting to heat or light. He was by then corresponding with journals for amateur naturalists and his notes on anemones were published in the *Blätter für Aquariem - und Terrarienkunde*. Later he showed the article to his uncle Sigmund who read it thoughtfully and congratulated him on a highly competent investigation.

At 17 Karl turned to zoology and began to collect and mount butterflies, beetles, moths, and other insects. The gentle youth regretted the necessity of killing the creatures and so limited himself rigorously to one example of each species. His private museum eventually grew to some 5000 specimens and at the suggestion of relatives he also began plant and fossil collections.

Nature study absorbed most of his youthful energies, but he also pursued such outdoor sports as swimming and mountain climbing. Long carefree summers were spent at the Austrian mountain hamlet of Brunnwinkl, where the family owned a lakeside summer home converted from a picturesque old mill. Another enthusiasm was music and as violinist he joined his three brothers in a string quartet.

At 19 Karl entered Vienna University as a medical student, putting aside his preference for zoology at his father's urging. He was an honor student, discovered nonetheless that medicine was not his calling, and in his third year abandoned it to continue with zoology. Frisch later credited his medical studies with providing an invaluable background in histology, anatomy, and physiology.

ZOOLOGIST. In 1908 Frisch enrolled in Munich's Zoological Institute, studied there under the internationally famed Richard von Hertwig, the developer of the germ-layer theory. He absorbed from Hertwig a then new viewpoint that transcended mere morphological description and ranged to basic inquiry into the natural adaptations of animals.

In field trips he explored a nearby wild bog and tramped the mountain paths of the Dolomites, repeating as a trained observer the nature study that had absorbed his youth. He was drawn also to the sea and set a vacation aside to take a special course at the Institute for Marine Research in Trieste.

A student research assignment involved a study of bees and that established what was to become a principal interest and main focus of his life's work. Years later he wrote that the sight of a beehive still intrigued him so that he would break off a planned day's walk and spend hours crouched in fascinated contemplation of the swarming insects.

Learned also at Munich was a histrionic device that he used later as a teacher. The occasion was an oral report on starfish behavior and to illustrate his talk he had a rag-doll starfish sewn for him by his obliging landlady. The exhibit drew laughter from fellow students and helped Frisch to overcome the shyness that he always felt when facing an audience. Thereafter he often dramatized his research with vivid illustrations

and was one of the first in his field to use audio-visual aids.

At 23 he returned to Vienna, completed his studies under the tutelage of experimental zoologist Hans Przibram, who headed a biological research station called the Vivarium. Frisch was assigned a doctoral thesis on the evolution of grasshoppers but while waiting for the seasonal egg to hatch he took up the study of minnows and became so engrossed in it that he obtained permission to continue it as an alternate project.

The investigation centered on the manner in which minnows change color to adapt to varying light. Frisch made nerve sections to demonstrate the neural pathways involved, later found that the light adaptations persisted even when both eyes of the minnow had been removed. He deduced that sensor cells existed in the skin pigment and used light beams to stimulate various body areas of blind minnows thus discovering a small translucent window in the cranium that served as a rudimentary third eye. A consultant in the work was uncle Sigmund, who advised on physiological research techniques.

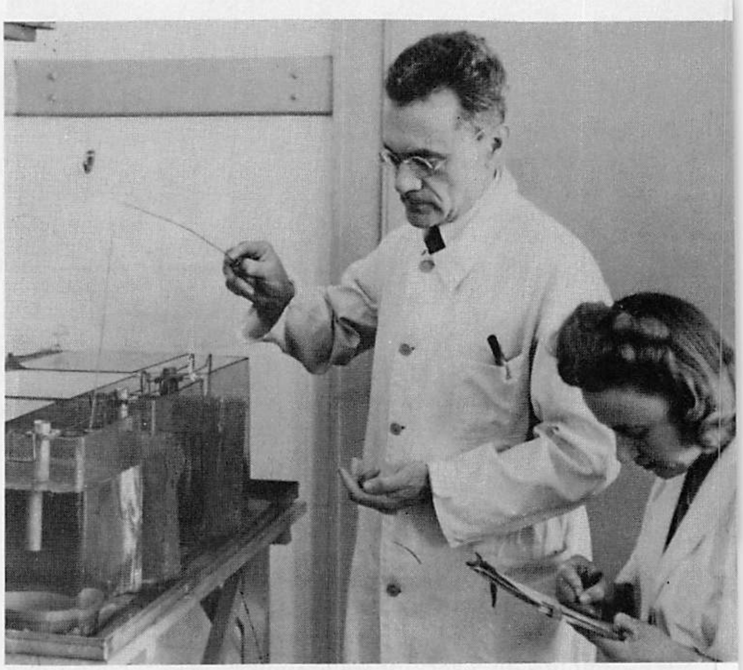
Frisch obtained his degree in 1910, returned to the Munich Zoological Institute as an assistant instructor, and during the next few years worked also as a vacationing guest researcher at the Statione Zoologica in Naples. On one excursion to Italy he climbed Mt. Vesuvius, got lost on the slope, but felt amply rewarded when he finally reached the peak and gazed into the awesome volcanic cone.

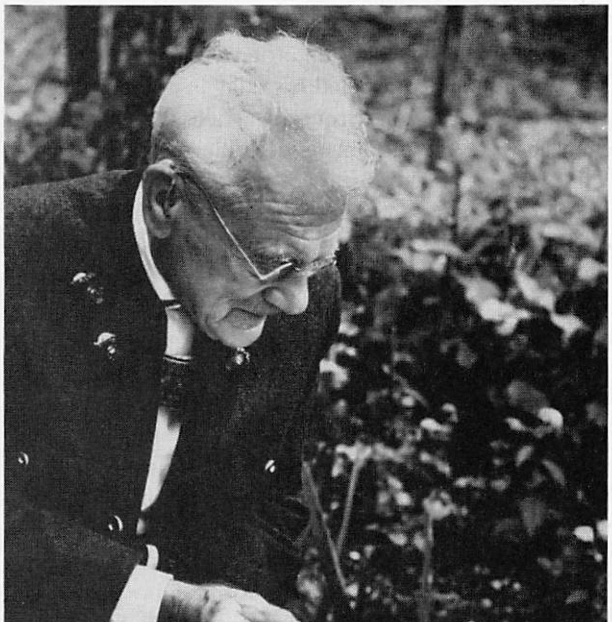
Resuming his minnow study, he wanted to disprove a then prevailing assumption that fish were color blind. He trained minnows to respond to color cues in experiments carefully designed to preclude other explanations. The findings aroused furious professional controversy but Frisch defended his work vigorously and the attention that the dispute aroused helped to establish his reputation as a promising young scientist. At 25 he was promoted to *Privatdozent* (lecturer) at Munich University.

He next conducted color-vision experiments with bees, doing much of the field work at the family home in Brunnwinkl. He set out blue dishes filled with sweetened water and gray dishes with unsweetened water, and the bees soon learned to ignore the gray while clustering thickly around the blue. Experimenting simultaneously with several hives, he spent a busy summer hurrying from one location to another to observe results, and eventually enlisted a volunteer research staff comprised of uncles, cousins, and assorted house guests.

In 1914 Frisch was invited to demonstrate both bee and minnow color vision at a meeting of the German Zoological Society at Freiburg. Unfortunately his minnows became sick when transferred to the Freiburg water and the local bees were so well fed that they

To prove that minnows respond to biological odors, he adds to a tank of minnows water from a tank that held a pike. The minnows reacted by hiding, even though no predator pike was physically near them.





In his garden he prepares both to mark bees and to study their color sense. Clover and a dish of sugar water are set out on a yellow surface to attract them.

Frisch in 1951 drives his wife, children, and grandchildren to a picnic. Daughter Helen, second row right, assists him, and his son Otto is a zoologist.

displayed scant interest in his dishes of sugar water. The threatened fiasco was saved when he made a last-minute discovery of some hungry bees foraging in a vegetable garden at the society's meeting place. Frisch hastily conditioned the bees to a color response, staged a successful demonstration, then enjoyed a dramatic triumph. As he concluded his talk, Frisch displayed a colorplate illustration from an article on the subject, then laid the plate on a picnic table near the garden. The bees swarmed around, then clustered thickly on the blue segments of the plate. Said Frisch: "This was entirely unexpected, and absolutely convincing."

MEDICAL INTERLUDE. The outbreak of World War I disrupted scientific work and Frisch returned to Vienna. He was rejected for army service because of poor eyesight, then volunteered to assist his brother Otto who was a surgeon and departmental head at Rudolfinerhaus Hospital in a Vienna suburb.

The hospital became a receiving station for the severely wounded and during the first month of war the 100-bed hospital was packed with some 400 cases. Frisch recalls that many of the casualties "were in a pitiful state with dirty, suppurating wounds, covered with vermin, and frequently suffering also from infectious diseases." He also noted that typhus was a constant threat and that lice particularly liked the padding inside plaster dressings.

Frisch worked as a medical aide for the next four years, assumed ever larger responsibilities as he supervised vermin control, served as x-ray technician and anesthetist, even performed amputations and other difficult surgery under medical supervision. He became particularly interested in bullet fractures of the leg and he published a major paper on the subject in collaboration with Otto. From these experiences he considered taking up medicine again, but a short leave at Brunnwinkl brought home the fact that he was "finished for the company of animals."

He established a bacteriological laboratory, improvising a facility in the hospital basement. He wrote: "I acquired the necessary, and of necessity very one-sided, special knowledge at the Institute of Hygiene. As we made our own culture media, our costs were low. Work there was in plenty." The laboratory provided quick diagnoses in occasional cholera and frequent dysentery and typhoid cases, helping to avert an epidemic.

He also instructed the nursing staff in bacteriological procedures and expanded the course into a small book, *Six Lectures on Bacteriology for Nurses.* Nurse Margarethe Mohr assisted him with the work, preparing the drawings, and in 1917 the two were married. The union produced four children, Johanna, Marie, Helen, and Otto, who followed his father into the field of zoology.

THE WORK. Frisch returned to Munich as assistant professor in 1919. During the next few years he served as a professor at the universities of Rostock and Breslau, then in 1925 succeeded his old mentor Hertwig as director of the University of Munich's Zoological Institute.

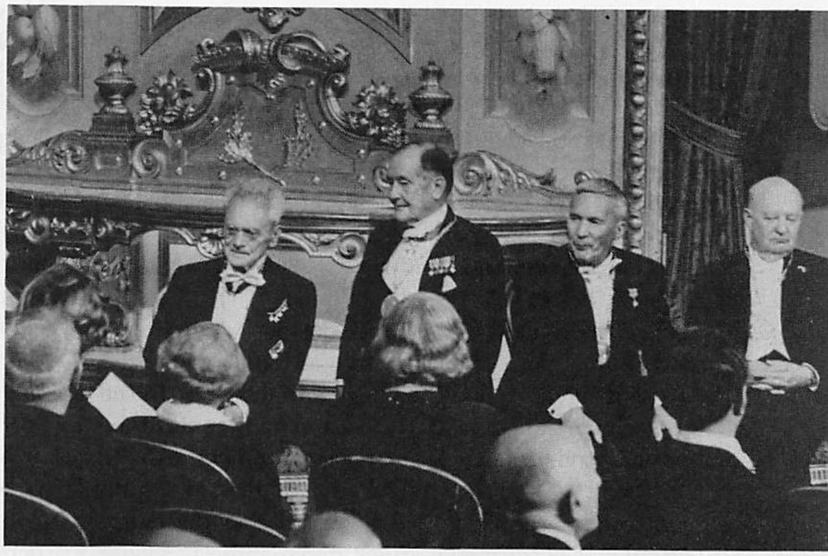
He took over antiquated quarters so crowded that lecture courses were held in the hallways and the ruinous state of the postwar German economy offered no possibility of financial aid from his own country. Frisch turned to the Rockefeller Foundation in the United States, secured a grant, and rebuilt the institute as one of the finest such facilities in Europe.

Frisch visited the United States to conduct grant negotiations, toured American and European zoological centers to obtain ideas on a model center, then personally designed every feature of the new Munich institute. It included an aquarium, an insectarium, a tropical house, a bees' house, an ant house, and the basement was set aside for cave-dwelling creatures that preferred dark moist quarters. Each division had its own culture rooms, and the large lecture hall was provided with the most modern audio-visual equipment. One guiding principle was that the institute was to be designed for the well-being of the animals, as well as convenient for the staff.

Incorporated were numerous ingenious features that later became standard for such centers. Ant colonies were set up on artificial island sites surrounded by water moats so that they were free to roam in a natural habitat while being unable to escape.

In designing the bees' house Frisch took account of the fact that they do not thrive in places situated above a subterranean watercourse. Someone suggested that water diviners should test the area and while Frisch was

Winner of the prestigious Balzan Prize, Frisch prepares, left, with Italian scientist Arangio Ruiz for a lecture he was to deliver to the Lincei Academy in Rome.



The 1963 Balzan Prizes were awarded at the residence of Italy's president in Rome, right. Other winners were American historian Samuel Eliot Morison, from left to right, Soviet mathematician Andrei Kolmgorov, and renowned composer Paul Hindemith.

skeptical of that art he decided that "it was best to judge by facts." He hired not one but five diviners, compared their reports, found them in complete disagreement with one another. He wrote: "I therefore put my bees' house in the place I considered most convenient, and never bothered about water-divining again."

The rebuilding project stretched over a period of seven years, most of the time consumed by long delays brought about by financial negotiations, and in the interim Frisch proceeded with imaginative investigations in the old quarters. In one project he demonstrated the hearing of minnows, teaching them to respond to the feeding signal of a whistle; the work was much impeded by the fact that the laboratory was crowded into a small nook in an area that thronged with the traffic of high-spirited students from other departments.

Frisch directed and supervised other experiments demonstrating how minnows maintain equilibrium in water and the uses to which they put senses of taste and smell. In one notable study he showed that the puncture of a minnow's skin releases an odor that immediately alerts other minnows to danger. A subsequent study showed that the mechanism was common to most but not all freshwater species and Frisch wrote: "Nature in her inventiveness scorns schematic solutions, and has thought of a variety of protective devices to ensure the survival of a species against terrific odds."

His greatest interest was the bee, a love affair that spanned more than three decades of investigation. In 1919 he extended previous studies of the bee's feeding habits; the question that now concerned him was how the colony found its way to a food source located by scouts. He wrote: "It was clear to me that the bee community possessed an excellent intelligence service, but how it functioned I did not know. This gave me no rest."

He marked bees with paint to observe the behavior of particular colony members and he learned that when a scout returned with nectar it performed a distinctive dance on the honeycomb that greatly excited other foragers who immediately flew off to collect the food. Frisch called it "the most far-reaching observation of my life" to which he and his students ultimately devoted more than 70 different and in-depth studies.

Much of the work was conducted at the Brunnwinkl retreat. One early trial was designed to test how far afield foragers ranged, the method being to mark scouts with paint, set out food dishes at various distances, and keep track of results through signals relayed by observers strung along the course. In one instance Frisch crouched patiently for four hours beside a dish and was finally rewarded when a scout bee arrived; he signaled the news by blowing a cow horn. Posted on a nearby hill was brother Hans, a professor of law, who passed on the word by ringing a cow bell, and another participant completed the relay with a trumpet note. A fourth observer waited at the hive and was thus alerted to watch for the returning bee and time its arrival. Much later when equipment became available, similar experiments were conducted with a field telephone network.

Frisch continually refined the experiments, seeking such information as how bees assimilated details of direction and distance and how they conveyed the

information to other members of the hive. The work was again interrupted by a world war but in August, 1944, at Brunnwinkl he made the exciting observation that the honeycomb dance was performed in a way to convey an entire message.

After passing the winter in feverish impatience, Frisch took up the work again as soon as the bees were stirring the next year. In a long series of experiments he sealed the scent glands of bees to eliminate that source of communication, then set out food dishes at sites carefully surveyed for direction and distance. He observed the hive day after day, noting the least change in the dance movements, and finally decoded "the language of the bees."

He learned that a circular round dance symbolized a food source close at hand while an equally stylized tail-wagging dance indicated a greater distance. In the tail-wagging performance the bee ran up the side of the hive in a straight line, executed a neat semicircle to the left, then repeated the straight run and made a second semicircle to the right. Frisch found that the dance pattern was performed in quick step to indicate a close food source, the rhythm slowing progressively to signal greater distances, and he was able to work out time-distance ratios on a closely calibrated scale. A final discovery was that the bees indicated direction in terms of the sun's location and the direction of gravity. If the dance pattern pointed straight up the hive, opposite to gravity, the flight path for food lay in the sun's direction. Straight down the hive meant away from the sun and other directions were signaled by corresponding changes in angle.

Frisch published his investigations in 11 books and more than 130 articles. The bulk of his writing was scientific, but he also enjoyed the role of public educator and infused his love of nature into clear and lucid popular works, such as his classic *The Dancing Bees* and *Man and the Living World*. In 1967 he produced *A Biologist Remembers*, a slim and modest autobiography in which he recounts both mistakes and triumphs and gives generous credit to all who had helped him.

The shared 1973 Nobel Prize crowned his career at age 86. He received other awards, such as the American Philosophical Society's Magellanic Prize, UNESCO's Kalinga Prize, and Switzerland's prestigious Balzan Prize. He holds honorary degrees from half a dozen great universities, belongs to as many leading scientific societies in Austria, Germany, Sweden, England, and the United States.

THE MAN. A reserved man, shy and gentle, Frisch has often seemed more at ease with his bees and minnows than in human company, and his life has been almost totally absorbed in his work. In his autobiography he recalls wryly that even on his honeymoon he was fretting impatiently to get back to his experiments on the scent training of his bees.

Much of his most productive work was done amid social chaos imposed by a violent era of history. In the 1920s he had to pick up the threads of his career in a war-shattered Germany whose inflation was so ruinous that it made his professorial salary almost meaningless. He was at one point so poor that he had to sell an old pair of shoes in order to supplement the family's meager food budget.

The Nazi period posed grave new dangers because of his partial Jewish descent. In 1941 the University of Munich was ordered to dismiss Frisch, but school officials procrastinated while friends intervened in quiet negotiations. The dismissal order was later withdrawn and he was somehow spared from further persecution. One probable reason was that his services were urgently needed to combat a bee disease that threatened the honey crop.

In the last phase of the war his beloved Munich Institute was severely damaged by bombs. His home at nearby Harlaching was completely destroyed. He poked through the still smoldering ruins to salvage what little he could, collected also some personal papers that he dared not let the Nazis find, then retreated to his Brunnwinkl home in Austria.

The American occupation restricted travel between Germany and Austria and for a time he was cut off from his old Munich associates. In 1946 at 60 he accepted a new post as zoological director at the University of Graz and during the next five years helped to rebuild that war-shattered institution. In 1949 he also paid a second visit to the United States. He presented a lecture on the vision, chemical sense, and language of bees at 17 universities and scientific institutions, which was a triumphant scientific tour, but he confessed himself a bit apprehensive about the trip because it marked the first time he had ever traveled by airplane.

The trip was also significant because it again brought him into contact with the scientific community outside Germany. The war had cost him not only his papers and valuable research time, but also nearly ten years of isolation. Said he: "Scientific work must be international and cannot prosper if confined in a cage. I have learned more during these three months, in both personal and scientific matters, than in the three previous years at home."

Frisch returned to the University of Munich in 1950 and remained there until he retired eight years later. Today at 91 he lives quietly in Munich, still collecting the insect specimens that fascinated him all his life.

Some of his last investigations were directed at still unsolved riddles of the innate time sense of bees. He says of the unfinished quest: "Science advances but slowly, with halting steps. But does not therein lie her eternal fascination? And would we not soon tire of her if she were to reveal her ultimate truths too easily?"

SUMMING UP. By Frisch: "Every single species of the animal kingdom challenges us with all, or nearly all, the mysteries of life."